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ScienceDirect

Procedia Computer Science 48 (2015) 73 – 76

Procedia Computer Science

International Conference on Intelligent Computing, Communication & Convergence

(ICCC-2015)

Conference Organized by Interscience Institute of Management and Technology,

Bhubaneswar, Odisha, India

Decision support model for automated railway level crossing system using fuzzy logic control

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Abstract

This paper aims to discuss a decision support model for automated railway level crossing (LC) using fuzzy logic control (FLC) for providing robust decision making at unmanned railway level crossings, to save the overall operation time, to avoid any accidental fatalities, and to eliminate human errors. The decision support model proposed here provides intelligent decisive action signals as similar to a human brain (e.g. during arrival and departure of trains at railway level crossing). FLC model is designed which recognizes the events (i.e. arrival and departure of trains) and accordingly output action signals are generated (i.e. to warning siren, control actions for opening and closing of gates). This type of model can be implemented in unmanned railway level where the chances of accidents are higher and reliable control operation is required. Three primary inputs to the specified model are considered based on visual, acoustic, and vibration. This novel system makes use of all these three parameters as input for its decision taking parameters, which increases the robustness of this model as compared with previously proposed models where the input is dependent on a single event. The FLC structure implemented to generate this model is multiple input multiple output (MIMO) system.

Peer-review under responsibility of scientific committee of International Conference on Computer, Communication and Convergence (ICCC 2015)

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doi:10.1016/j.procs.2015.04.152

Keywords: Fuzzy logic; Automated system; Railway level crossing; MIMO;

1. INTRODUCTION

Indian railway network has a level crossing on an average of 1.5 kms and about 75-80% of all level crossing accidents occurred at unmanned LCs. Development of an intelligent and robust control system is the need of the time and in public interest also. The unmanned level crossings are not only the bottlenecks in train operation, but also a major cause for the accidents and fatalities and hence such a scenario demands development of more reliable automated control systems.

At present several approaches have been proposed and being carried out by using different sensors and control systems to improve the control actions at LCs but the systems are not effective during their applications. As referred through several works and reports on LCs across the globe, including different control techniques implemented for its automation, it can found that making the system intelligent[7] can result to achieve its purpose of avoiding accidents, saving human life, and robust operations to control gates at LCs. For this fuzzy logic control system (FLC) is considered to serve the purpose because it is based on a logical system which is much closer to human thinking and action than traditional hard logical systems[2].

A variable structure fuzzy logic controller developed for this purpose and in another study presented a systematic procedure for constructing a multi-input multi-output fuzzy controller[3, 6]. Similarly a method of rule based fuzzy logic was developed using a forward and backward inference[10]. The control rule is the core of the fuzzy inference process, and those rules are directly related to a human being's intuition and feeling[1, 11].

The proposed work aims to contribute towards creating ambient intelligent decision support model which can intelligently understand the events by *visual*, *acoustic* and *vibrational* recognition signal inputs so that the needed control action can be performed automatically and instantly to maximize the human safety while minimizing the response time. Fuzzy logic is considered to be an ideal tool similar to human brain which work from approximate data, extract meaningful information and produce crisp solutions. In the following sections the proposed system architecture and model for the fuzzy controller are presented.

2. PROPOSED SYSTEM ARCHITECTURE

In the existing systems for the railway level crossing uses a single sensing element to recognize the events of arrival and departure of trains at the LC, in some of the previously proposed systems when the sensors are at distant places from the LC, it requires a wired/wireless communication system for signal transmission to LC in order to perform various control actions. The system proposed here uses instantaneous inputs at the LC and by means of intelligent system designed using fuzzy logic generates the predefined control action signals. The generalized concept of the proposed model is the control action signals generated by the FLC that is similar to the decisive actions taken by a normal human being (while a train is approaching LC, gates should be closed and when it is going away, gates should be open). The human intelligence and decision taking at any real-time event incorporates inputs through the basic five senses present in the body, out of all these senses to recognize an event, three inputs are concentrated here (i.e. vision, hearing and feel). Hence the present model considered the following three senses as inputs to the system:

- Vision based (by video capturing devices)
- Hearing based (by Acoustic Emission sensors)
- Feel/touch based (by vibrational sensors/ load cells)

These set of multi inputs to the fuzzy system renders it as a multi-input fuzzy inference system.

The corresponding outputs of the system are the indicators (i.e. traffic signal indicators and warning siren) and the LC gate control action (i.e. mechanical opening and closing of LC gates) signals. Signal indicators and gate control action signals corresponds to multi-output of the proposed system.

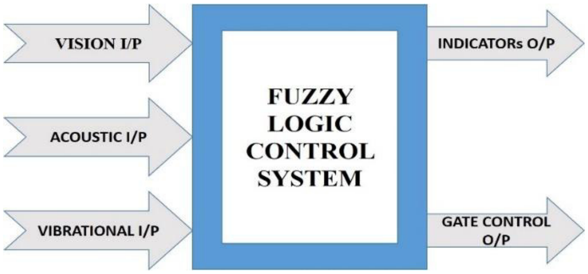

Fig. 1. MIMO system architecture

The complete architecture of the proposed system exhibits the characteristics of multi-input-multi-output (MIMO) system, including three basic inputs (vision, acoustic, vibrational) and there corresponding outputs (indicators and gate control signals) as depicted in Fig.1.

3. FUZZY LOGIC CONTROLLER

Fuzzy logic controller is the core of a fuzzy system, which integrates fuzzy logic and having different methods by which a linguistic control strategy can be incorporated[6]. The linguistic variables are in the form of natural language (such as high, medium and low) and are represented as fuzzy sets[4, 8]. It forms the base of the fuzzy control system[9].

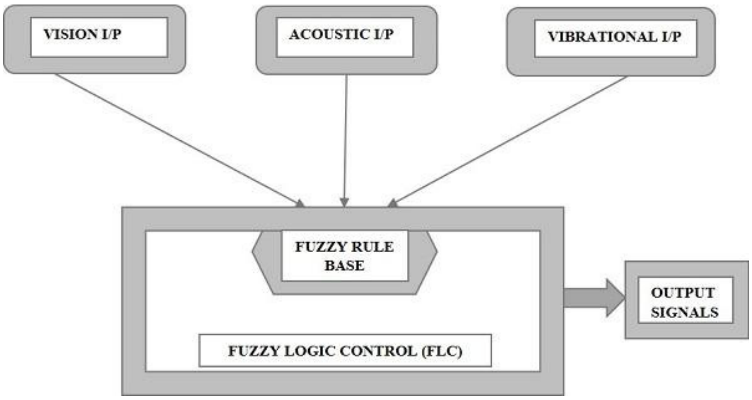

Fig. 2. Three inputs of the proposed FLC

3.1 Fuzzy Input Variables

The first input to our system is the vision based recognition of arriving train. The second input of the system is the acoustic emission. The third input to the system is the vibration of the approaching train (Fig. 2). All the received input stimuli are then normalized and leveled.

3.2 Fuzzy Logic Rule Base

Fuzzy functions represents a system, where either an input or the output channel is a different modality from the representational system with which it is being used[5]. A sample of fuzzy rule list is produced in Table 1. Each individual set of input corresponds to a defined control action. Basically the rule base is compromised of the events with different input levels which corresponds to the determination of the output control action signal, respective events are such as: No arrival of train, arrival of train but at far distance from the LC, arrived or passing through the LC, and passed through the LC.

Table 1. Some fuzzy rules for the FLC

VISION I/P	ACOUSTIC I/P	VIBRATION I/P	INDICATOR O/P 1	INDICATOR O/P 2	GATE CONTROL O/P
ZERO	LOW	LOW	NO SIREN	GREEN	OPEN
ZERO	LOW	MEDIUM	NO SIREN	GREEN	OPEN
…	…	…	…	…	…
ZERO	MEDIUM	MEDIUM	SIREN	ORANGE	CLOSE
HIGH	HIGH	HIGH	SIREN	RED	CLOSE

3.3 Fuzzy Output Variables

The first output of the system is indicators (siren and visual signals). The second output of the system is the gate control signal (mechanical opening and closing of gates at LC).

At the output stage of FLC, defuzzification is performed, all the actions that have been activated are combined and converted into a single non-fuzzy output signal[6], which is the control signal of the system.

4. CONCLUSION

The increased number of accidents at railway LCs both at manned and unmanned clearly indicates the pitfall of the present system being used at railway level crossings, for which the proposed decision support model can give an effective solution. Accidents at level crossings are mainly caused due to human error and system failure to detect the trains at LCs. The proposed method can be helpful in detecting the arrival and departure of the train at the railway level crossings to assist an intelligent automated system to control the gates and the road traffic for the safety of human life or to avoid accidents. This novel concept for detecting arrival of train at the railway level crossing using three different inputs namely: vision, acoustic, and vibration in real-time by means of a FLC system for train detection at both manned and unmanned LCs can provide more robust solution.

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